Application of Hydrostatic Knowledge in the Construction of Forming Tools

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Abstract. Not only traditional (conventional) but also non-traditional (unconventional) methods are used in metal forming. Unconventional methods will, as it turns out, have more scope than in the past, especially in relation to environmental constraints. One of the methods of unconventional forming is forming in a liquid environment, more precisely – sheet metal forming by applying hydrostatic pressure. This is the subject of the present.

Keywords: *forming; fluid; tool; deep drawing; application*

1 Introduction

The principle of hydrostatic forming consists in the action of hydrostatic all-round pressure of liquids in the forming tool and the punch. Among the methods used for sheet metal drawing, methods using a flexible - plastic environment for this purpose occupy an important place. In this case, it is the so-called unstable tool. It has a number of advantages over fixed tools - savings in production costs for the tool, especially in the production of smaller series of moldings of complex shapes. The forming process is also simplified by eliminating the need to fit the active parts of the tool and by eliminating complex holders. In the following text, attention is paid to the issue of deep drawing of sheet metal using a special tool for laboratory conditions.

2 Theoretical findings

At a constant temperature, the volume of the liquid changes minimally under the influence of pressure, and this is essentially a phenomenon and the consequent knowledge that liquids are minimally compressible. If the pressure acting on the liquid increases, its volume decreases by a certain, very small value. When the pressure is reduced to the original value, the liquid immediately occupies the original volume. The liquids are therefore perfectly flexible. The compressibility of liquids is evaluated by a known compressibility coefficient, which is defined by the following relation :

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$$\gamma = -\frac{1}{V}\frac{dV}{dp} \tag{1}$$

where: V is the initial volume of the liquid, - dV is the elementary decrease in volume caused by the elementary increase in pressure by the value dp.

The compressibility coefficient is different for different liquids. At high pressures it decreases, with increasing temperature it usually increases. Its value for water at 20 ° C is: γ = 4,998. 10-10 (Pa^{-1}). Forming in a liquid medium uses, resp. physical knowledge, known as Pascal's law, is applied to it. According to FIG. 1: let there be an incompressible liquid in the vessel with a density ρ which is in equilibrium in the gravitational field of the earth.

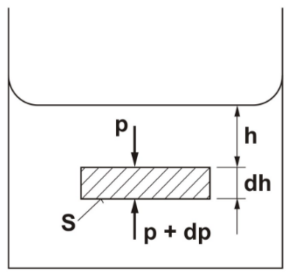

Fig. 1 To derive relationships

At a depth h below the surface of the liquid, an element with the volume of an elementary cylinder with a base S and a height dh is extruded. The selected elementary amount of the liquid is affected by its own weight (volume force), as well as the compressive forces (area force) of the remaining liquid. The compressive forces acting on the upper and lower bases of the elementary cylinder have a vertical direction. The compressive forces acting on the cylinder shell have a horizontal direction. Equilibrium conditions require that the vector sum of all forces be zero. Since the weight of the selected amount of liquid has the value $dG = \rho\ Sg\ dh$, resulting compressive force of the vertical direction oriented upwards (buoyancy):

$$df = (p+dp)\ S - pS = Sdp. \tag{2}$$

The equation condition follows from the equation:

$$\rho\ Sg\ dh - Sdp = 0. \tag{3}$$

After modifying and integrating equation (3) will be:

$$p - \rho\ gh = const. \tag{4}$$

The potential of the Earth's gravitational field at depth h below the surface of the liquid can be expressed by the relation $V = - gh$, and equation (4) goes to the form:

$$p + \rho V = const. \tag{5}$$

Equation (5) has general validity. It can be written: if the incompressible liquid is at rest in any force field, the sum of the potential energy of its volume unit and the pressure is the same everywhere in the liquid. If the liquid is under higher pressure and does not occupy too large a volume, so that the potential changes in the liquid are small, the term ρV in equation (5) can be considered practically constant and from equation (5)
the relation $p = const.$, which is actually an expression of *Pascal's law* of uniform pressure distribution in fluids. According to *Pascal's law*, it is: the pressure in a fluid that is in

equilibrium spreads integrally, that is, in all directions and with the same magnitude. This knowledge is applied in the following text in the field of sheet metal forming. [5,6,7,8]

3 Application

In the field of surface forming, materials based on sheet metal semi-finished products are processed. For this reason, forming in a hydraulic environment has a great perspective. With this type of forming, forming tools working precisely with the use of a liquid, which in most cases is used as a replacement for one active element of the tool. It is therefore also an economic reduction in the cost of their production. Liquid forming itself is not new at present, but somehow still remains in the shadow of all-metal tools, despite its advantages. This fact is surprising because the method is able to largely eliminate the negative effects of production processes, because it uses water as an active element, i.e. an element that does not burden the environment. Figures 2 and 3 show several tool solutions that certainly meet the required parameter imposed on them.

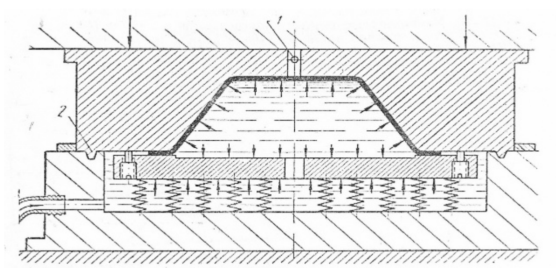

Fig. 2 Hydraulic drawbar 1- venting, 2- labyrinth sealing groove

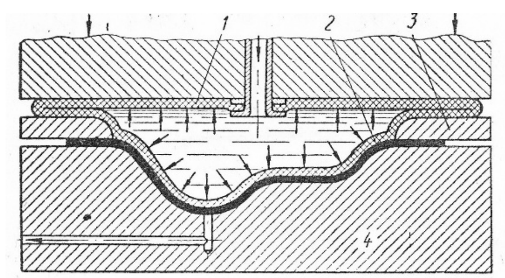

Fig. 3 Hydraulic towing toll 1 – sealing rubber cushion, 2 – molded part, 3 – holder, 4 – rod

4 Experimental part

A forming tool was constructed for experimental work, in which relevant knowledge of fluid mechanics is applied. In FIG. 4 and 5 are photographs of the tool. The suitability of the hydraulic solution and the comfort of the tool operator, which is at the appropriate level, was verified. The findings are sufficient and it is only a matter of time before the solution will be optimized, respectively. supplemented by the necessary peripheral elements to make the operator more comfortable and to reduce the time required for the production of the sheet metal part.

5 Description of the toll

The forming tool for hydro-drawing is constructed of two basic parts. The lower part is a block of plexiglass. M6 screws are pressed into the block to secure the upper part of the tool. An opening for the supply and discharge of pressurized fluid is led out at the side. The entire lower part is assembled with screws and stands on four legs. A rubber seal is pushed onto the M6 screws. The upper part is a duralumin plate into which the necessary shape for the extract is milled. The cavity must not have sharp edges and the transitions must be rounded. The part is drilled with the lower part and slides on the M6 screws screwed into the tank. A pressure fluid is admitted into the tool and by its action the sheet metal cut is evenly pressed into the recess in the upper part of the tool. In FIG. 6 is a diagram of the connection of the tool to the hydraulic system.

Fig. 4 Experimental hydraulic towing tool (assembly)

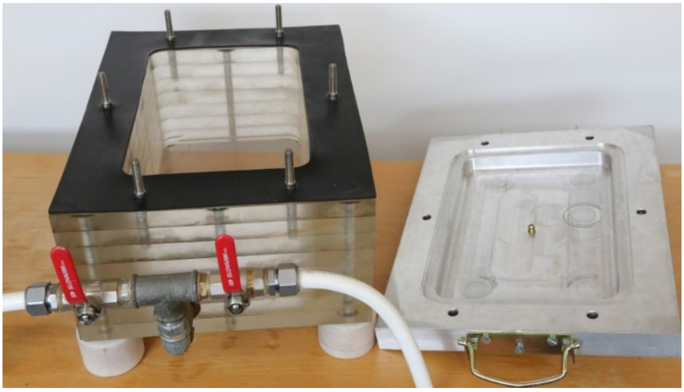

Fig. 5 Experimental hydraulic towing tool (disassembled)

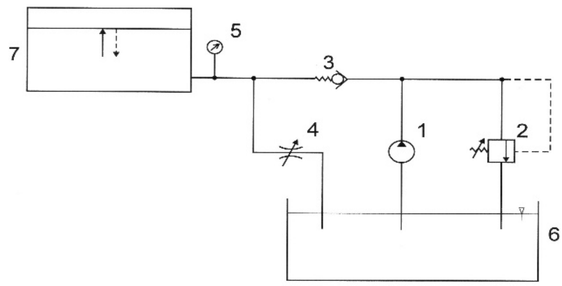

Fig. 6 Wiring diagram for the hydraulic towing tool in the hydraulic system 1 – gear pump, 22 – PV safety valve, 3 – JV check valve, 4 – SV throttle valve, 5 – Manometer, 6 – tank, 7 – toll-forming chamber

5.1 Technological procedure for working in the tool

- Insert the sheet metal cut on the top of the tool,
- slide the upper part onto the M6 screws,
- screw in M6 nuts,
- switch on the pump, check the value of the liquid pressure, the formation of the extract,
- switch off the pump, drain the liquid from the tank,
- dismantle the upper part, put it aside,
- select the art and visually check the surface of the extract,
- place the part on a pallet.

When water is used as a medium, although it is relatively most available, there is a risk of surface corrosion of the extracts. Its advantage is that it does not represent an ecological burden on the environment. The oil is optimal for this work in terms of tribological characteristics. The appropriate oil viscosity should be tested. The oil clearly takes precedence over another medium. Disadvantage - in the event of an accident, oil leaks into the environment.

6 Discussion

Physical knowledge in the field of fluid mechanics is a great source from which it is possible to draw almost indefinitely. When applying (generally) any finding from this sphere - reflected in the technical solution - there is almost always one limitation. It is the impact of using the solution on the environment. Nowadays, this condition will probably become limiting in the application of any new solution. It will be necessary to respect the fact that the earth is one huge ecosystem, regardless of political boundaries. For the sphere of production in the field of engineering, it will be necessary to focus on ecological solutions. It is for this reason that the submitted contribution was also created. Solutions that can respect environmental constraints will find their application. The use of water as a basic element of living nature in the production process is one of the ways leading to this goal.

7 Conclusion

The present paper addressed a topic which is unfortunately not in the forefront of the interest of sheet metal parts manufacturers to the extent it deserves. The biggest advantage of hydromechanical drawing is the achievement of the coefficient $m = 0.3$, in one operation, which has not yet been achieved by another procedure. This will be reflected in a reduction in the number of operations and consequently in a reduction in the price of tools. The price is up to ten times lower for some moldings. Related to this is the possibility of using hydromechanical drawing even with a smaller number of yields. The fact that only the die has a precise shape of the molding and the die is actually formed by a pressurized fluid greatly helps to reduce the cost of the tools. The forming process takes place in a liquid medium, therefore the surface of the material, which can be surface-treated, is not damaged. The method allows the drawing of intricate moldings even with a hole in the bottom. The drawing depth is practically not limited from the point of view of procedure. The undeniable advantages of hydromechanical drawing are: - savings in pulling conical and parabolic parts, - the sheet is thinned by only 2-3% during the process, ie the same sheet thickness is maintained in the whole molding, - the corrugation during drawing causes a greater deformation, which improves the mechanical properties of the material. The disadvantage of the described procedure is the increase in pulling force, which results in the need to use more powerful presses. The above also applies to the holder. Within the workplace at KTI FME of the University of Žilina in Žilina, the following issues concerning the area of the use of hydromechanical traction are also solved. Experimental work has been performed using this method, although not yet in the field of volume forming. [4] The intention is to expand the scope and focus intensively on surface forming with the application of knowledge from hydromechanics. Experimental work has confirmed the suitability of this type of forming, especially for piece production, and the application of the tool expands the sphere of physical knowledge usable in sheet metal forming.

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